

# Ships Entry into Floating Docks with Tugs Assistance

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## Abstract

Ships' parameters have increased in the biggest part of ship building and ship repairing yards. There are installed with bigger floating docks in the yards, but in the same time water areas and channels are still left the same or in some cases - decreased water areas close to dry and floating docks. New ships maneuvering possibilities and new types of tugs assistance can better deal with bigger dry and floating docks, which is studied in this article and study results are presented.

## Keywords

*Floating and Dry Docks; Ships Maneuverability; Ship's Steering; Tugs Using*

## Introduction

Ships building and ships repairing yards are located in the parts of ports which are unable to be used for other ports facilities, like stevedoring, passenger terminals and have limited entrance channels and water areas parameters, such as width of the channel, ships turning basin diameter. In the same time, ships' size is increasing: container vessels, bulk carriers, tankers, cruise ships etc (Baublys, 2003). Ships building and especially ships repairing yards try to install bigger floating docks for the bigger ships in the same water areas (Paulauskas, 2000).

New ships maneuvering possibilities, new type of the port tugs (Paulauskas, 2011), new very accurately ports navigational systems (E-Sea Fix, 2003) can increase navigational safety in complicated yard areas and as the final result stimulates ships parameters to increase in ships building and ships repairing yards (Paulauskas, 1998; Paulauskas, 2000; Paulauskas etc, 2009; Stern, 2004).

Ships maneuvering possibilities must be studied to ensure navigational safety during ships sailing to or from dry or floating docks and limits of hydro meteorological conditions must be found for such

ships maneuvers. Following the increasing ships parameters tendency in the same time, many ships building and ships repairing yards stay in the same places and have no possibilities to increase approach channels parameters and water areas (PIANC, 1995, Klaipėda port maps, 2011). This situation request more accuracy of the ships steering (Paulauskas, 1998; Paulauskas etc, 2009), to use more correct ships maneuverability possibilities, new higher accuracy navigational systems (E-Sea Fix, 2004), new tugs possibilities (Paulauskas, 2011).

As the case study is presented Klaipėda Western Ship yard situation, which is planned to install new bigger floating dock (PANAMAX type of dock) (Klaipėda port maps, 2011).

## Ships Building and Ships Repairing Yards Situation in Ports

Ships building and ships repairing yards in old ports are located at the end of the port, having narrow entrance or approach channels because in past during ships building and ships repairing yards constructions, yards were orientated to a relatively small ships.

In the same time typical port business increase, for example in East Baltic ports cargo flow increase from 45 million tons in 1990 up to 250 million tons in 2011 and close to ships building and ships repairing yards, developed new ports terminals and water areas have decreased (Klaipėda port maps, 2011).

As the example at Klaipėda port in Malku bay in which ships repairing yard was build as well as this bay planned just for the ships repairing yard, during last decades, which itself is planning to install new bigger dock for PANAMAX type ships with length up to 250 m (in the past planned maximum length of ships was up to 200 m), has developed 5 new cargo terminals. (Fig. 1 – Fig. 2) (Klaipėda port maps, 2011).

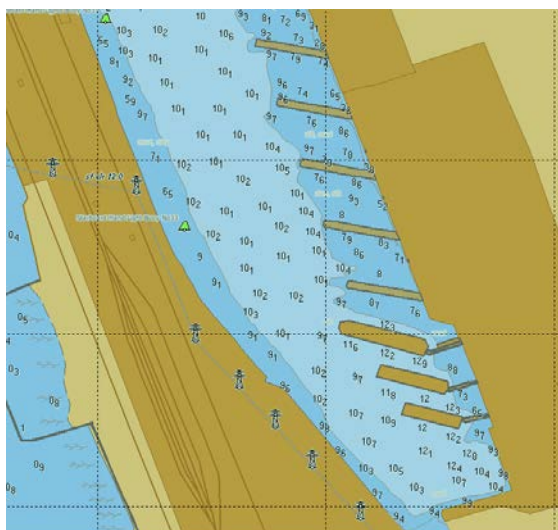


FIG. 1. ORIGINAL STAGE OF KLAIPEDA SHIPS REPAIRING YARD AND WATERS

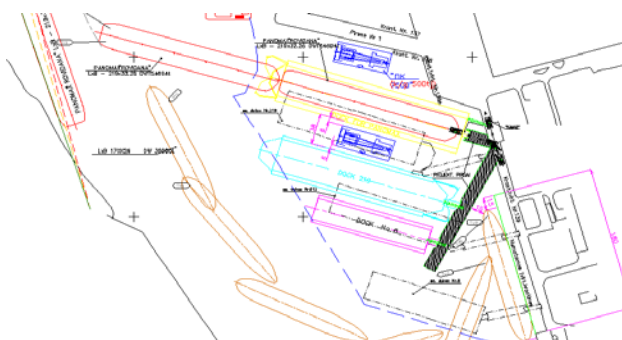


FIG. 2. KLAIPEDA WESTERN SHIPS YARD AFTER DEVELOPMENT OF TERMINALS IN MALKU BAY AND IMPLEMENTATION OF THE NEW FLOATING DOCK FOR PANAMAX TYPE SHIPS

Gdansk port, which was planned for ships of up to 200 – 250 m length, has accepted ships in docks with length up to 295 m (Fig. 3, Fig. 4).

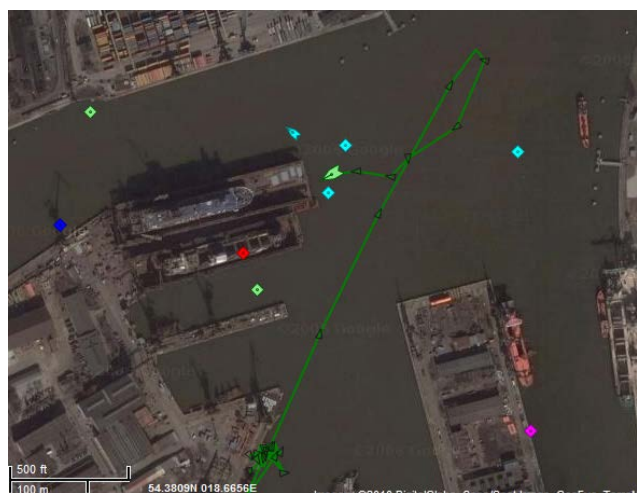


FIG. 3. SHIP „SEALAND CHAMPION“: L = 292 M; B = 32 M; DWT = 59840 T ENTRY TO FLOATING DOCK IN GDANSK SHIPS REPAIRING YARD. MINIMAL DISTANCE TO OPPOSITE SIDE IS 370 M



FIG. 4. SHIP „SEALAND CHAMPION“: L = 292 M; B = 32 M; DWT = 59840 T ENTRY IN GDANSK PORT (2010.06.08)

New ships and new type of tugs, including navigational systems with high accuracy make it much provide for bigger ships in the same limit areas in comparison with original plans.

### Theoretical Basis for the Ships Size Increasing in Dry and Floating Dock Areas

Navigational safety in very limited areas can be ensured on the basis of 3 main factors:

- Ship's steering in docks area in case of very low ship's speed;
- Ship's possibility to stop in a very short distance (close to dock entrance);
- Ship's turning possibilities in a very close to dock entrance in case of ship's speed is close to 0 knots.

Ship's steering in dock area with very low speed could be reached in case of using tugs on ship astern with short tug line. Horizontal tug pull force, which can be reached by tug, could be calculated as follows (Paulauskas etc. 2008):

$$F_h = F_T \cdot \cos \alpha \quad (1)$$

Where:  $F_T$  - tug pull force;  $\alpha$  - tug line vertical angle.

Tug pull force ( $F_T$ ) should be equal to the ship's propeller pull force ( $F_p$ ) at least on Dead Slow speed ahead, which can be calculated as follows (Paulauskas, 1998; Paulauskas etc, 2009):

$$F_p = K_1' \cdot \rho \cdot n_p^2 \cdot D_p^4 (1 - t'') \quad (2)$$

Where:  $K_1'$  - ship's propeller hydrodynamic coefficient, can be taken as 0,2;  $\rho$  - water density, for many ports

can be taken as  $1000 \text{ kg/m}^3$ ;  $n_p$  -propeller's revolution per s (rps);  $D_p$  -ship's propeller diameter;  $t''$  -propeller's propulsion coefficient, can be taken as 0,2.

Ship's stopping on short distance can be made by ship's active stopping and tug's on astern short tug line assistance. Main formulas for the ship's active stopping parameters: stopping distance and stopping time, can be calculated as follows (Paulauskas, 1998; Paulauskas etc, 2009):

$$S_a = \frac{m}{2k_{in}} \ln \frac{k_{in} \cdot v_0^2 + (F_p + F_T)}{k_{in} \cdot v^2 + (F_p + F_T)} \quad (3)$$

$$t_a = \frac{m}{\sqrt{k_{in}(F_p + F_T)}} \left( \arctg \sqrt{\frac{k_{in}}{F_p + F_T}} \cdot v_0 + \arctg \sqrt{\frac{k_{in}}{F_p + F_T}} \cdot v \right) \quad (4)$$

Where:  $m$  - mass of the ship, including added mass;  $k_{in}$  - ship's inertia coefficient, can be taken from ship's stopping parameters in ship's maneuvering manual;  $v_0$  - initial ship's speed;  $v$  - actual ship's speed;  $F_T$  - tug pull force.

Ship's turning possibilities close to dock entrance with a very low ship's speed can be made by thrusters or by tug or tugs by pull/push method. Tug's horizontal push force should be equal to  $F_T$ , that means (Paulauskas etc, 2008):

$$F_h = F_T \quad (5)$$

Tug's pull horizontal force will be equal to:

$$F_h' = F_T \cdot \cos \beta \quad (6)$$

Where:  $\beta$  - vertical angle of the rope goes from ship to tug.

For the good ship's steering in case of close to the dock entrance, it is necessary to have thrusters or tugs pull/push forces not less as (Paulauskas etc, 2009);

$$F_h' \cdot x_1' = Y_a \cdot x_a' + Y_c \cdot x_c' \quad (7)$$

Where:  $x_1'$  - distance from thrusters or tugs push/pull place till Ship's pivot point, which in case ship's moving ahead located at about  $1/3L$  ( $L$  – ship's length

between perpendiculars) from ships middle to forward and in case of ship's moving astern pivot point located about  $1/3L$  astern from ship's middle (Strem, 2004);  $Y_a$  - aerodynamic force;  $x_a'$  - distance from aerodynamic force centre on ship to pivot point:  $Y_a$  and  $x_a'$  can be calculated according to (Paulauskas, 1998; Paulauskas etc, 2009);  $Y_c$  - current force, created on ship;  $x_c'$  - distance from current force centre (ship's hull underwater centre) to pivot point:  $Y_c$  and  $x_c'$  can be calculated according (Paulauskas, 1998; Paulauskas etc, 2009; Paulauskas etc, 2008).

Ship's propulsion forces is exclusive from the above formula and these forces and moments could be used temporarily as reserve for the ship's increasing maneuverability. In the same time, it is necessary to take into account usual situation in ship building and ships repairing yards, that ship has not functioning the main engine during ship's repairing services (main engine is in repairing process as well).

Propellers scour caused by propeller stern screw effect usually is not taken into account in many cases, but this could have very important influence on tug's pull force (Paulauskas, 2011). The jet velocity caused by the rotating screw, so called induct jet speed can be calculated as follow (EAU, 2006).

$$v_{01} = 1,6 \cdot n \cdot D_p \cdot \sqrt{k_T} \quad (8)$$

Where:  $k_T$  - thrust coefficient of the screw, which could be taken for study case 0,30 – 0,40.

Distance on which induct jet speed is influencing, could be calculated for tug as follows (Paulauskas, 2011):

$$v_0' = k_v \cdot v_{01} \quad (9)$$

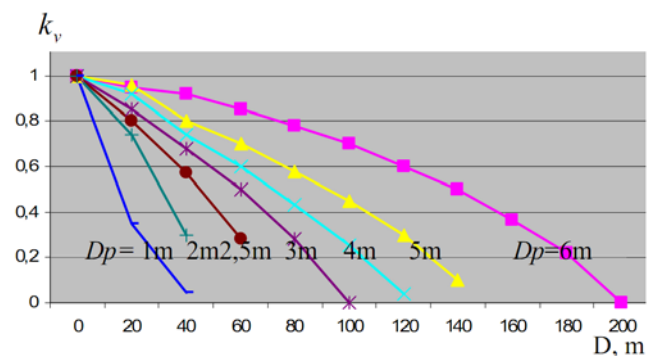


FIG. 5. INDUCT JET SPEED COEFFICIENT, DEPENDS ON TUG'S PROPELLER DIAMETER AND DISTANCE BETWEEN PROPELLER AND CHECKING POINT (SHIP'S HULL), D

Where:  $k_v$  - induct jet speed coefficient, depending on tug's propeller diameter and distance between propeller and checking point (ship's hull), was received by theoretical investigations and experimental testing on real tugs, presented on Fig. 5.



FIG. 6. SHIP'S PULL BY TUGS, USING PUSH/PULL METHOD

Tug propellers induct jet speed directly having influences on ship's hull (create resistance dependent towage ship's hull form) square by induct jet, which is equal of the propeller screw square, calculated as follows (Paulauskas, 1998; Paulauskas, 2011):

$$A = \pi \left( \frac{D_p}{2} \right)^2 \quad (10)$$

Additional force, which is created by propellers screw, could be calculated as follows (Paulauskas, 2009; Paulauskas, 2011):

$$F' = C_y \cdot \frac{\rho}{2} \cdot A \cdot (v_0')^2 \cdot n_p \quad (11)$$

Where:  $C_y$  - hydrodynamic coefficient, can be taken from 0,5 up to 2,0 (2,0 in case if propeller's screw acting perpendicular to ship's hull as vertical wall on the big draft towage ship);  $n_p$  - number of tug propellers.

Finally total tug pull force in case of pulling by pull/push method, when tug is located close to the ship, can be calculated as follows:

$$\sum F_T = F_T \cdot \cos \alpha - C_y \cdot \frac{\rho}{2} \cdot A \cdot (v_0')^2 \cdot n_p \quad (12)$$

Last formula shows that if vertical angle of the tug rope is very big (close to 90°), pull force could be very low or in some cases could make negative effect,

which means propeller's screw created by towage ship's hull could be as bigger as tug pull force.

### Practical Examples and Calculations Entry Ship in Dock

As the practical calculation and testing example is taken in Klaipeda port Western Ships Yard floating dock and PANAMAX type of ship ( $L = 216$  m), which has functioning the main engine and use 2 tugs with "azipod" propulsion equipment („tractor" type), which has pull power 30 T and 50 T. Both tugs use pull/push method for the ship steering. Ship's main engine is strong enough for the ship stopping and do not use tug on ship's astern with short tug line (Paulauskas, 2006; Paulauskas, 2009).

Water area near floating dock is narrow and limited because on opposite side of the entrance to the floating dock was built quay wall which is used for the big ships mooring. Navigational situation and distances between floating dock entrance and quay wall and ship on opposite side are presented on Fig. 7 and Fig. 8 and ships sailing parameters are presented on Fig. 9, which have received on full mission Simulator SimFlex Navigator (SimFlex, 2009) and checked on real ships.

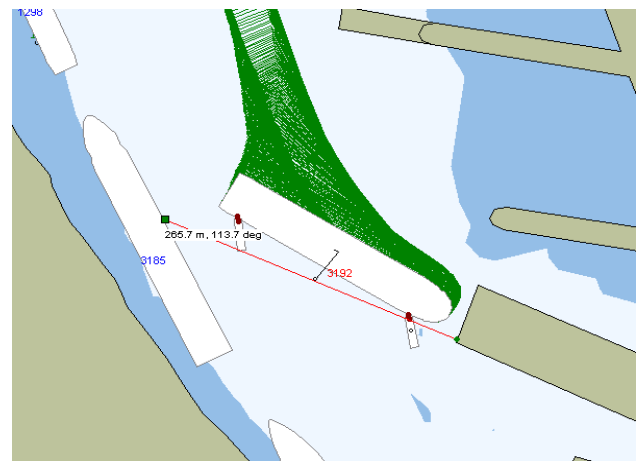


FIG. 7. PANAMAX TYPE SHIP ( $L = 216$  M) SAIL TO ENTRANCE OF THE FLOATING DOCK IN MALKU BAY WITH TWO TRACTOR TYPE TUGS AND MINIMAL DISTANCE BETWEEN ENTRANCE TO FLOATING DOCK AND SHIP ON OPPOSITE SIDE

For the practical bollard pull study was taken on the real ship which made mooring and unmooring operations in Klaipeda port with "Tractor" type tugs, and based on the experimental results obtained from analysis on real ships, simulator SimFlex Navigator (SimFlex, 2009) was calibrated. Quay walls, which are located perpendicularly at the current direction, were



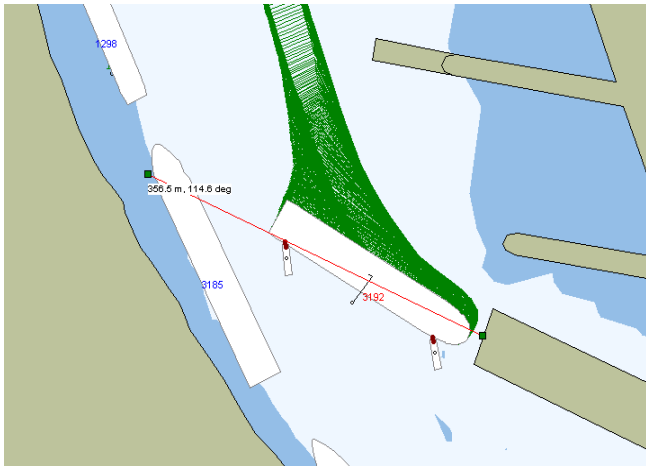


FIG. 8. PANAMAX TYPE SHIP (L = 216 M) SAIL TO ENTRANCE OF THE FLOATING DOCK IN MALKU BAY WITH TWO TRACTOR TYPE TUGS AND MINIMAL DISTANCE BETWEEN ENTRANCE TO FLOATING DOCK AND QUAY WALL ON OPPOSITE SIDE

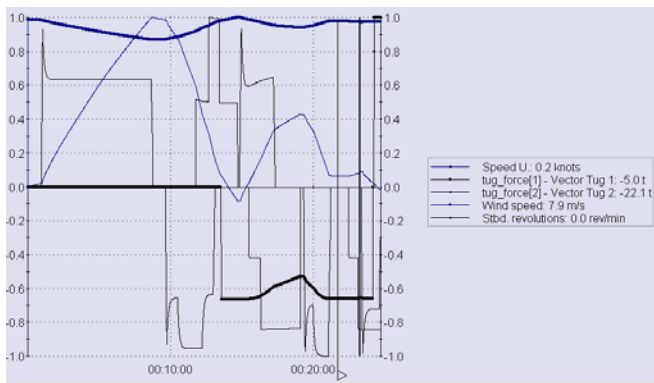


FIG. 9 SHIP'S, PRESENTED ON FIG. 7 AND FIG. 8 SAILING PARAMETERS

used for testing on SimFlex Navigator Simulator. For test, container vessel was employed which had overall length 215 m, width 32,2 m, draft 9,5 m, displacement 39740 m<sup>3</sup>. For mooring, two "tractor type" tugs each having 300 kN bollard pull force were used in the course of operation. During unmooring operations tugs used push/pull method and short tug ropes method. Current speed to quay wall direction was 0,5 knots in case of tugs using push/pull method, explained on fig. 6 and current speed to quay wall direction was 0,8 knots in case of tugs used short tug ropes towage.

Test results in case of tugs using push/pull method dependent on time are presented in Fig. 10. (vertical line on Fig. 10 shows ship's actual position on Fig. 6). Vertical angles of tug ropes were 65 degrees on the ship fore and 60 degrees on the ship aft. Difference between total bollard pull of the tug and test case is presented on Fig. 11 (pull/push method)

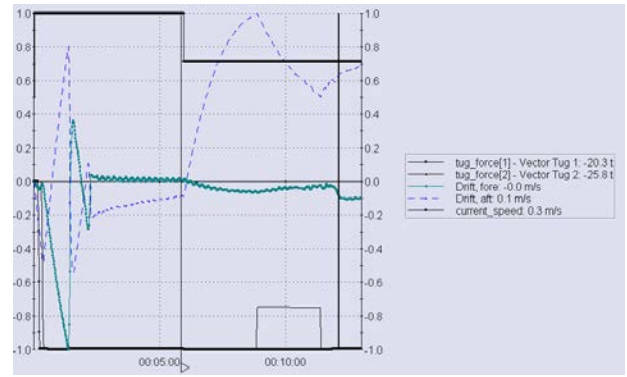


FIG. 10 CONTAINER VESSEL MOVEMENT FROM QUAY WALL TUGS PULL FORCE AND CURRENT SPEED DATA. FROM TIME 00.00 MINUTES UP TO 06.00 MINUTES, CURRENT SPEED WAS 0,8 KNOTS, AFTER 06.00 MINUTES, CURRENT SPEED WAS DECREASED UP TO 0,6 KNOTS. VERTICAL LINE ON FIG. 10 (TIME 12 MINUTES) SHOWS CONTAINER VESSEL POSITION PRESENTED ON FIG. 6

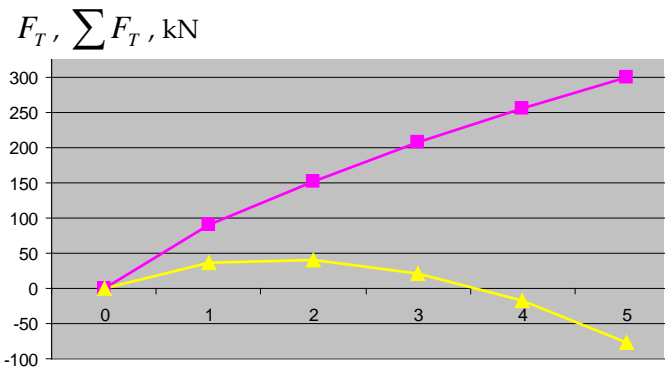


FIG. 11. 300 KN BOLLARD PULL POWER TUG ( $F_T$ ) (RED LINE) DEPENDS ON PROPELLERS REVOLUTIONS AND TOTAL TUG'S PULL FORCE  $\sum F_T$  (YELLOW LINE) USING PULL/PUSH METHOD IN CASE TUG LINE VERTICAL ANGLE 60°, TUG'S PROPELLER DIAMETER 2,0 M, NUMBER OF PROPELLERS 2, DISTANCE BETWEEN TUG'S PROPELLERS AND SHIP HULL 25 M.

Presented calculations, tested on real ships sailing to dry and floating docks. Based on the received results in some ships building and ships repairing yards, like in Gdansk, ships whose length is 294 m can entry into dry or floating docks in limited water areas close to docks, while ships can entry into docks in case of ration of the distance to the length of the ship up to 1,1 or some less times in good preparation but tugs real bollard pull situation must be taken into account.

## Conclusions

Development of the new terminals in traditional ports decreases water areas for ships building and ships repairing yards.

Navigational systems with new tugs, ships maneuverability possibilities and high accuracy

increase ships entry possibilities to dry and floating docks in very limited water (navigational) areas, in case of ration of the distance to the length of the ship could be up to 1,1 or less.

Theoretical basis, presented in this Article can be used for the limited conditions calculations entry ships to dry and floating docks.

Testing with the help/aid of full mission simulators and practical examples of sailing ships to/from dry and floating docks shows good correlation between theoretical and practical results

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